

Reconstituting Asteroids into Mechanical Automata

Completed Technology Project (2016 - 2017)

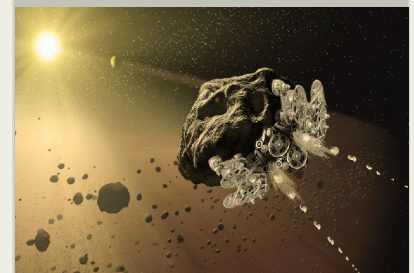


Project Introduction

The objective of this study is for Made In Space (MIS) to establish the concept feasibility of using the age-old technique of analog computers and mechanisms to convert entire asteroids into enormous autonomous mechanical spacecraft. Project RAMA, Reconstituting Asteroids into Mechanical Automata, has been designed to leverage the advancing trends of additive manufacturing (AM) and in-situ resource utilization (ISRU) to enable asteroid rendezvous missions in which a set of technically simple robotic processes convert asteroid elements into very basic versions of spacecraft subsystems (GNC, Propulsion, Avionics). Upon completion, the asteroid will be a programmed mechanical automata carrying out a given mission objective; such as relocation to an Earth-Moon libration point for human rendezvous. This technique will create an affordable and scalable way for NASA to achieve future roadmap items for both the Human Exploration and Operations Mission Directorate (HEOMD) and the Science Mission Directorate (SMD) such as Asteroid Redirect Mission (ARM), New Frontiers Comet Surface Sample Return, and other Near Earth Object (NEO) applications. It is estimated that an order of magnitude increase in NEO targets can be explored for the same mission cost with the RAMA approach compared to the SOA Asteroid Redirect Mission (ARM) architecture by removing the need to launch all spacecraft subsystems and instead converting the asteroid into them in-situ. Assuming the development trends continue for industry based AM methods as well as NASA and industry investments in ISRU capabilities, Project RAMA will create a space mission architecture capable of achieving the aforementioned NASA goals within a 20-30 year time frame. Furthermore, as described in the proposal, the identified study path will provide insight into near term Mission 'Pull' technologies worth investment in order to create the development roadmap for the proposed 'Push' technologies for achieving NASA's long term strategic goals.

Anticipated Benefits

This technique could some day create an affordable and scalable way for NASA to achieve future roadmap items for exploring the solar system. These techniques could be beneficial to scientific goals for understanding the solar system and its formation, as it is estimated that an order of magnitude increase in NEO targets could be explored for the same mission cost compared to the SOA. RAMA would enable this by removing the need to launch all spacecraft subsystems and instead converting the asteroid material in-situ. Assuming the development trends continue for industry based AM methods as well as NASA and industry investments in ISRU capabilities, Project RAMA will create a space mission architecture capable of achieving the aforementioned NASA goals within a 20-30 year time frame. Furthermore, as described in the proposal, the identified study path will provide insight into near term Mission 'Pull' technologies worth investment in order to create the development roadmap for the proposed 'Push' technologies for achieving NASA's long term



Artists depiction of an asteroid being reconstituted into a mechanical automata.

Table of Contents

Project Introduction	1
Anticipated Benefits	1
Primary U.S. Work Locations and Key Partners	2
Project Transitions	2
Organizational Responsibility	2
Project Management	2
Technology Maturity (TRL)	2
Technology Areas	3
Target Destination	3
Images	4
Links	4

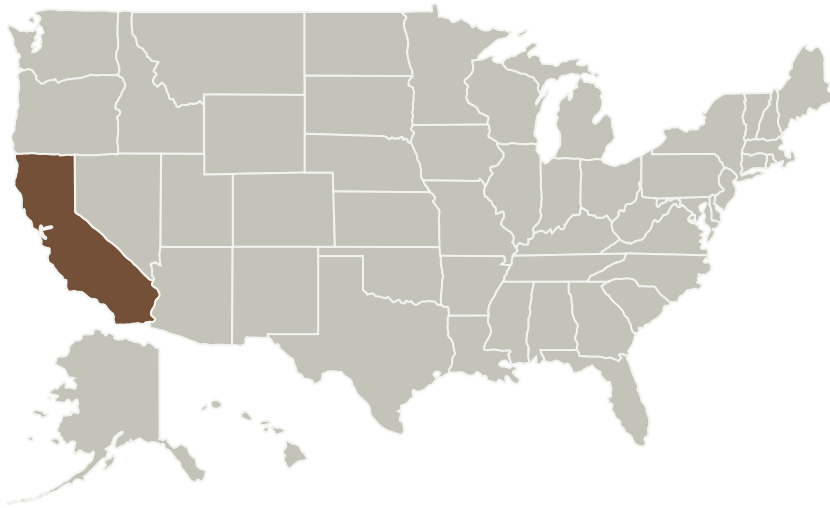
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strategic goals.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Made in Space, Inc.	Lead Organization	Industry	JACKSONVILLE, Florida
University of Central Florida(UCF)	Supporting Organization	Academia	Orlando, Florida

Primary U.S. Work Locations

California

Project Transitions

**July 2016:** Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Made in Space, Inc.

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

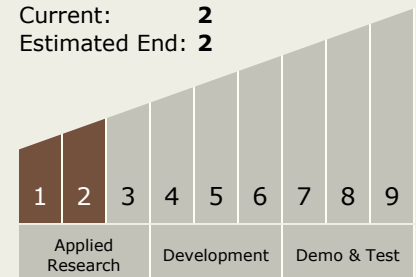
Program Manager:

Eric A Eberly

Principal Investigator:

Jason J Dunn

Technology Maturity (TRL)

Start: **1**Current: **2**Estimated End: **2**

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✓ **June 2017:** Closed out

Closeout Summary: Many interesting ideas have been conceived for building space-based infrastructure in cislunar space. From O'Neill's space colonies, to solar power satellite farms, and even prospecting retrieved near earth asteroids. In all the scenarios, one thing remained fixed - the need for space resources at the outpost. To satisfy this need, O'Neill suggested an electromagnetic railgun to deliver resources from the lunar surface, while NASA's Asteroid Redirect Mission called for a solar electric tug to deliver asteroid materials from interplanetary space. At Made In Space, we propose an entirely new concept. One which is scalable, cost effective, and ensures that the abundant material wealth of the inner solar system becomes readily available to humankind in a nearly automated fashion. We propose the RAMA architecture, which turns asteroids into self-contained spacecraft capable of moving themselves back to cislunar space. The RAMA architecture is just as capable of transporting conventional sized asteroids on the 10 m length scale as transporting asteroids 100m or larger, making it the most versatile asteroid retrieval architecture in terms of retrieved-mass capability. This report describes the results of the Phase I study funded by the NASA NIAC program for Made In Space to establish the concept feasibility of using space manufacturing to convert asteroids into autonomous, mechanical spacecraft. Project RAMA, Reconstituting Asteroids into Mechanical Automata, is designed to leverage the future advances of additive manufacturing (AM), in-situ resource utilization (ISRU) and in-situ manufacturing (ISM) to realize enormous efficiencies in repeated asteroid redirect missions. A team of engineers at Made In Space performed the study work with consultation from the asteroid mining industry, academia, and NASA. Previous studies for asteroid retrieval have been constrained to studying only asteroids that are both large enough to be discovered, and small enough to be captured and transported using Earth-launched propulsion technology. Project RAMA is not forced into this constraint. The mission concept studied involved transporting a much larger ~50m asteroid to cislunar space. Demonstration of transport of a 50m-class asteroid has several groundbreaking advantages. First, the returned material is of an industrial, rather than just scientific, quantity (>10,000 tonnes vs ~10s of tonnes). Second, the useless material in the asteroid is gathered and expended as part of the asteroid's propulsion system, allowing the returned asteroid to be considerably purer than a conventional asteroid retrieval mission. Third, the infrastructure used to convert and return the asteroid is reusable, and capable of continually returning asteroids to cislunar space. The RAMA architecture, as described in this report, was shown to be cross cutting through the NASA technology roadmap as well as the future goals of the greater aerospace industry. During the course of the study it was found that the RAMA technology path aligns with over twelve NASA roadmap missions across seven NASA technology areas, and has the opportunity to substantially improve the affordability and scalability of both the Human Exploration and Operations Mission Directorate (HEOMD) and the Science Mission Directorate (SMD) stated goals. The approach to studying this concept started with the development of Rock Finder, a rapid optimization tool for identifying suitable asteroids for utilization. In parallel to the Rock Finder development, a trade study was performed on various ISRU and ISM technologies. A technology roadmap was created to identify suitable technologies for turning asteroids into spacecraft. Rock Finder was then used to identify a single S-type asteroid, and a mission assessment was performed for a specific set of technologies, showing the feasibility of performing a RAMA style mission with the asteroid. The end results suggest that the RAMA architecture is a feasible way to automate a self-perpetuating suite of asteroid exploration, discovery, and utilization missions within a twenty to thirty year time horizon, demonstrating

Technology Areas

Primary:

- TX07 Exploration Destination Systems
 - └ TX07.1 In-Situ Resource Utilization
 - └ TX07.1.2 Resource Acquisition, Isolation, and Preparation

Target Destination

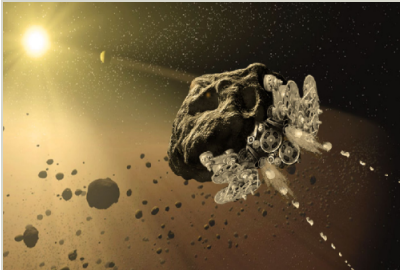
Others Inside the Solar System

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Images



Project Image

Artists depiction of an asteroid being reconstituted into a mechanical automata.

(<https://techport.nasa.gov/image/102252>)

Links

NASA.gov Feature Article

(<https://www.nasa.gov/feature/reconstituting-asteroids-into-mechanical-automata>)